Photo Double Ionization of Neon

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Double ionization of an atom by a single photon has been the topic of many investigations in the recent years. Most efforts have focused so far on helium [1,2] resulting in the complete determination of the final state (apart from the electron spins) at 1 eV and 20 eV above the threshold. Recent convergent close-coupling calculations by Kheifets and Bray [3] show a good agreement in shape and absolute scale of the fully differential cross sections with our experimental data. Besides helium also other noble gases have attracted some interest (see i.e. [4]) as they allow the study of the initial state's influence on the photo double ionization process.

We have tried to extend our highly successful technique of cold target recoil ion momentum spectroscopy [2] to measure the fully differential cross sections for photo double ionization of neon. This technique relies on the measurement of the momentum of both the electron and the doubly charged recoil ion. The second electron can then be calculated via momentum conservation. However, the error in the measurement of the ion's momentum scales linear with the ion's mass. It thus turns out, that the momentum resolution for the Ne^{2+} ion is not sufficient to achieve reasonably accurate cross sections.
Based on previous experiences with multi-hit detection techniques for molecular fragmentation [5] we have modified our experimental setup to detect both electrons up to 15 eV energy with a geometrical solid angle of 4π on the electron detector in addition to the recoil ion. This geometrical solid angle however is reduced by the pulse pair resolution of our detection system. Only signals which are more than 15 ns apart in time can be clearly resolved. This means that certain regions of the emission angles will be lost. With this setup, in contrast to our earlier experiment, the recoil ion is used only for background suppression, while the cross sections are obtained directly from the two electrons.

First experiments were performed at the bending magnet beam line 9.3.2 of the ALS with linearly polarized light. The Stokes parameter S_1 has been determined experimentally to $S_1 = 0.94 \pm 0.03$. Fig. 1 shows the energy sum of both electrons at a photon energy of 72.8 eV. The ^3P ground state and the ^1D first excited state of the Ne^{2+} recoil ion are clearly resolved. The ^1S second excited state is very weak and can be seen as a shoulder at 3.3 eV. The single electron energy distribution is shown in fig. 2. For the ^1D final state this distribution is basically flat as in the case of helium. For the ^3P ground state however the distribution has two peaks, one at the low energy end and the other at the high energy end. These are the result of single ionization and excitation to the $1s^2 2s 2p^5 3s\ ^4P$ state of Ne^+ with the ejection of a photo electron with 2.6 eV energy. The excited state then decays via autoionization by emitting an electron of 7.6 eV energy. This process is energetically possible only for the ^3P final state of Ne^{2+}.
Further analysis is still in progress and while fully differential cross sections have been obtained their interpretation is complicated as the regions of the final phase space which are lost due to the pulse pair resolution have to be taken into account. Based on these experiences we are currently

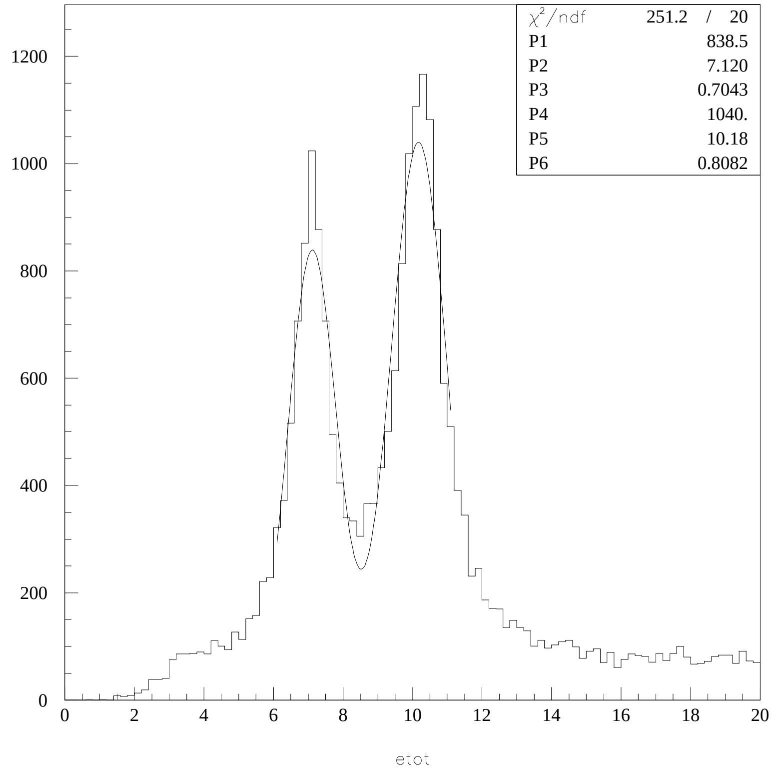

Figure 1: Energy sum of both electrons at 72.8 eV photon energy. The two lines result from photo double ionization events with the remaining Ne^{2+} ion in the ^{3}P ground state (line at 10 eV) and in the ^1D first excited state (line at 7 eV). The ^{1}S excited state is visible as a shoulder at 3.3 eV.

testing a detection system with improved pulse pair resolution. In addition future experiments are planned at other energies where the autoionizing state of Ne^+ will not be populated and where the ^{1}S state can be clearly seen above the background. Especially the ^{1}S state is of interest as it resembles the helium case most closely, although the electrons final state is an overlap of $\epsilon s\epsilon p$ and $\epsilon p\epsilon d$ states whereas in helium only $\epsilon s\epsilon p$ is allowed.

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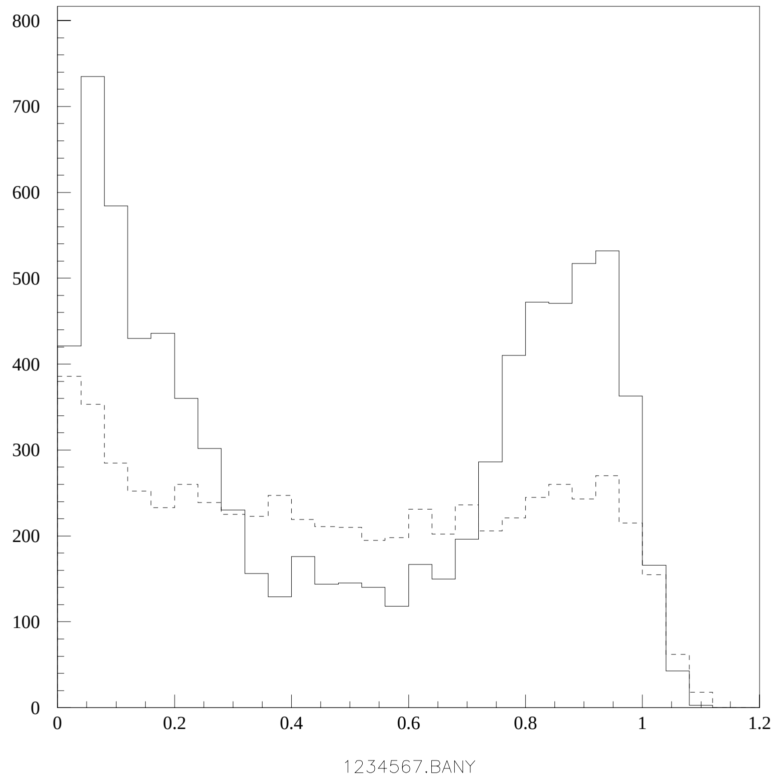

Figure 2: Single electron energy distribution at 72.8 eV photon energy: solid line ^{3}P final ionic state, dashed line ^{1}D final ionic state.

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